QUATERNARY GEOMORPHOLOGY OF FLINDERS ISLAND

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ABSTRACT

Flinders Island consists of a mountainous Palaeozoic basement ridge, flanked by coastal plains built largely of Cainozoic sediments and minor lavas. Sea-level fluctuations have been important in coastal dune building and in developing coastal marine erosional and depositional features.

Quaternary dune series recognised include (from oldest to youngest) aeolian calcarenite, aeolianites, unconsolidated parabolic dunes, beach ridges and frontal dunes. Dunes are mainly calcareous on the west coast and siliceous on the east coast, probably due to difference in source and distribution of contributing materials. The wide east coast plain displays an extensive lagoon development, including old inland lagoons, lagoons of the parabolic dunes and coastal barrier lagoons.

The coastal plains display evidence of past higher sea-levels, dating from the Tertiary. Possible Pleistocene levels have been observed at 200-250 feet (60-75 m.), 100-120 feet (30-37 m.), 60-70 feet (18-21 m.), 25-30 feet (7.5-9 m.) and 10-15 feet (3-4.5 m.) above MLWS. Marine and littoral shell beds are associated with the last three levels, which are assigned Riss/Würm and Holocene. Some dunes extend below present sea-level indicating past lower sea-levels.

INTRODUCTION

Flinders Island, the largest of the Furneaux Group in Bass Strait, has been visited briefly a number of times between 1957 and 1970 by the authors. The resulting geomorphologic observations, associated with aerial photographic study, are discussed. The valuable groundwork provided by the soil survey (Dimmock, 1957) and unpublished regional surveys by Tasmania Mines Department officers (Blake, 1947;

Everard, 1950) made much of the basic work of this paper possible. The geologic aspects of the authors' studies, based in part on the geomorphologic observations, are presented elsewhere (Sutherland and Kershaw, 1971). A map of the geomorphologic features of the Island, plotted from aerial photographic interpretation and/or field work, is presented with this paper. Despite the limitations of a study largely based on reconnaissance field work, it is considered the results should provide a framework for future more detailed work. Flinders Island occupies an important place in the coastal physiographic evolution of Southern Australia. It has an exceptional range of dune development.

The Island is bounded by about 120 miles of coastline, exposed dominantly to westerly winds, but strong easterly movements are also experienced particularly in the spring and summer. During storms in Bass Strait waves do not reach heights of these oceanic coasts. On the eastern coast wave action is modified by the shallow offshore slope. Tidal ranges determined from measurements of intertidal ecological features (R. C. K.) indicated a range of 10 feet (3 m.) on the west coast, 5 feet (1.5 m.) at Lady Barron on the south coast, and at least 3 feet (1 m.) on the east coast. The west coast value is close to that of the north Tasmanian coast.

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GEOMORPHOLOGY

Flinders Island may be divided into two basic geomorphologic units: (A) the highlands, controlled by the Palaeozoic basement; (B) the coastal lowlands.

A. THE HIGHLANDS

The mountain systems on Flinders Island trend approximately north-north-west. The sharply etched granite Strzelecki Peaks massif (2550 feet), and Mt. Razorback (2285) feet), is a five square mile block bounded by rounded foothills. To the north it is separated from the Darling Range block (Pillingers Peak, Mt. Leventhorpe, Mt. Counsel), by a plateau at 250-400 feet elevation.

The trend is then north westerly from Brougham Sugarloaf (1484 feet) towards Mt. Arthur. North-east from Lughrata, a northerly trending granite ridge outcrops through a cover of high dunes. Between Leeka and Palana, an arc of granite peaks from Cape Frankland includes The Paps (580 feet), Mt. Tanner, Mt. Boyes, Mt. Blyth and Mt. Killiecrankie (1035 feet).

A surface of rounded hills and wide valleys flank the granite mountains. The soils are old (Dimmock, 1957). This surface may have been cut by, and was possibly a coastal plain during the highest Cainozoic sea-level stands. It is slightly higher than the Cainozoic basalt flow surface (Sutherland and Kershaw, l.c.) that forms the highest part of the plateau separating the granite massifs. Several rounded granite hills on the coastal plain include Vinegar Hill (351 feet), The Patriarchs and The Quoin.

Interpretation of the Topography

The Bassian Rise which includes the highlands of Flinders Island is probably

Figure: Map text: Geomorphological sketch map of Flinders Island showin[g] topographic highs, drainage: distribution, density and orientati[on] of dunes and lagoons, and some Quaternary sea-level features. Draw[n] largely from aerial photograph interpretation by R. C.Kershaw.

partly a tectonic feature (Jennings, 1959a). Highland and some island group trends of the Bassian Rise suggest elevated fault blocks. These were probably formed by N. N. W. to N. W. faulting associated with the late Mesozoic/Cainozoic movements responsible for present structural features of Tasmania, Bass Strait, and Southern Victoria (Jennings, 1959a; Spry and Banks, 1962; Richards and Hopkins, 1969). Flinders Island topography suggests fault blocks mostly with south westerly facing scarps and, possibly, downward tilts to the N. E. Aerial photographs show a strong N. W. joint trend in the granite basement (see also Hughes, 1959). Most of the basic dykes associated with the late stage cooling of the granite trend N. E. (Sutherland and Kershaw, l.c.), suggesting that the N. W. joint set is later and probably reflects the late Mesozoic/Cainozoic uplifts. Both the Strzelecki Peaks and the Darling Range show marked alignments parallel to this N. W. jointing. In the former area these have noticeably controlled the drainage system. Prolonged steep faces of these ranges may be fault controlled. Extensive grit beds skirt their flanks (e.g. Loccota Grit) suggesting alluvial fan development on short steep streams over long periods as would be expected on a resistant scarp. Some scarps such as that east of Whitemark to Ranga (Everard in Hughes, 1957), are interpreted as Pleistocene sea-cliff lines, perhaps originally fault controlled.

The topographic breaks across the highlands may be the result of cross faulting as indicated by the marked N. E. lineament in the granite just south of Mt. Hauland and Pillingers Peak, and by the sharp N. N. E. lineaments in the submarine topography to the north of Flinders Island (Jennings, 1959a). Thus the eastern coastal plain north of Memana suggests a possible fault controlled concentration of past drainage as the alignment is more or less S. W. - N. E. The break between Strzelecki Peaks and Darling Ranges may be similarly controlled.

B. THE LOWLANDS

1. THE COASTAL PLAINS

These significant features of the landscape are divisible into eastern and western units. The eastern plain is the more extensive occupying almost half the Island.

(1) The Western Plain (Plate 1)

There are three levels:

(a) The present coastal plain including the backshore and the bench cut to 20-30 feet above MLWS best developed at Whitemark and Marshall Bay.

(b) An old coastal plain between 50-150 feet as at Loccota and west from Centre Hill.

(c) A plateau-like surface that slopes gently to the east from 400 feet in the Ranga district to merge with the Eastern Plain.

The present coastal plain between one and two miles wide becomes very narrow to the south. The old coastal plain is partly the remains of benches and sediments of Pleistocene high sea-levels. Its edge is marked by a steep scarp near Ranga. Above this is the plateau-like surface, partly formed by basalt.

(2) The Eastern Plain (Plate 2)

This surface, mostly below 30 feet above MLWS, is characterised by dune and lagoon topography.

South of the plateau-like surface east of Ranga, the plain slopes from the Strzelecki massif to the east coast. West from Vinegar Hill the rise inland on

Bootjack Plain from the 25 feet bench is gradual. There are low E-W ridges. East from Vinegar Hill E.N.E. - W.S.W. dunes and narrow marshy lagoons rest on the almost flat surface.

From Cameron Inlet north to The Patriarchs the plain rises gently for six miles inland to The Dutchman.

There are three important features in this area:

(i) The beach ridges and lagoons of the coastal barrier.
(ii) A series of E.N.E. - W.S.W. parabolic dunes and associated lagoons.
(iii) Nelson Lagoon, the largest lagoon area on the Island, now fully drained.

The plain extends 15 miles north from The Patriarchs to the Arthur River and 10 miles inland to the limestone hills of the Lughrata District. This gently sloping surface has few lagoons. A narrow belt of E.N.E. - W.S.W. dunes near the coast, extends inland at "Wingaroo". North of Memana there is a probable former marine embayment with old low, E.N.E. - W.S.W. dunes on the inland margins.

The Eastern Plain slope persists to the edge of the continental shelf. Whether emergent or submergent features predominate is a matter of viewpoint.

2. THE DUNE SYSTEMS

The following dune systems are recognised in this study:

(1) Palana Limestone Dunes.
(2) Inland Siliceous Dunes.
(3) Trousers Point Aeolianite Dunes.
(4) Unconsolidated Parabolic Dunes.
(5) Beach Ridge and Frontal Dunes.

(1) Palana Limestone Dunes.

Red-brown soils (Ranga Association of Dimmock) derived from Palana Limestone and containing limestone boulders are widespread on the western coastal plains. Old dunes can be discerned on this undulating surface. In places they exhibit aeolian bedding. Considerable depths of this limestone or aeolian calcarenite occur in some areas. Sink holes are common (Everard, 1950) and a cave is known near Ranga. This cave, described by Hope (1969) contains floor deposits over 8,000 years old and appears to be stranded from an old drainage level about 40 feet above the adjacent creek.

<u>Distribution</u>

These dune limestones occur principally in (a) the Palana, (b) the Lughrata and (c) the Ranga districts.

(a) At Palana limestone rises from sea-level to 400 feet on both sides of Pratts River. It is partially covered by Holocene sand dunes along the coast while inland there is a typical red-brown soil horizon. South-west of Palana it forms an off-shore stack.

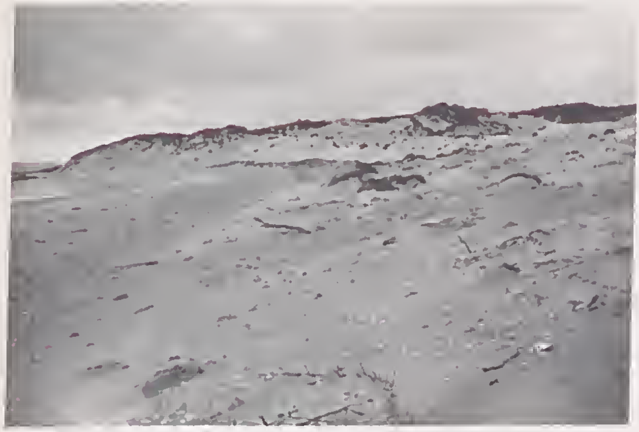
(b) At Lughrata the limestone is cut by a bench at 20-30 feet (6-9 m.) above MLWS. It rises to 500 feet inland over a core of granite hills.

(c) At Ranga the limestone rests on the granite basement to over 200 feet.

Several smaller areas occur, e.g. at Killiecrankie Bay where a 20 feet thick

1. Western Coastal Plain, south from Loccota. Cape Barren Island in the background.

2. Eastern Coastal Plain, looking east from Vinegar Hill toward Cameron Inlet.



3. Blow-out in Lughrata Sand Dunes, north from Palana, looking north-easterly, profile of Palana Limestone Dunes exposed.

4. View of Lughrata Sand Dunes near Loccota looking south toward Trousers Point.

limestone arch shows aeolian bedding.

Nature of the Limestone

These limestones resemble those found in southern Australia (Hills, 1940; Coulson, 1940; Sprigg, 1952; Boutakoff, 1963; Gill in Jennings and Mabbutt, 1967) which are considered to be of dune origin. Evidence for a similar origin for the Flinders Island deposits is given by Dimmock (1957). The present writers support this view.

At Palana a limestone capped profile of old sand dunes (oriented at right angles to the shore) is overlain by unconsolidated dune sands (Plate 3). Similar limestone "profiles" rest on sands elsewhere, e.g. north of Killiecrankie.

Aerial photograph study reveals the outline of parabolic dunes in each of the limestone areas. Some dunes with aeolian bedding are easily recognised in the field (Plate 10), but the oldest are visible only on photographs. Incipient subsurface consolidation in the unconsolidated calcareous dunes of Lughrata Sand at Marshall Bay suggests an early stage in Palana Limestone Dune formation.

Origin and Development

The Palana Limestone Dunes are found inland from the unconsolidated Parabolic Dunes at Lughrata but are overlain by these dunes at Palana. The series evidently extended below sea-level, *vide* the sea stack near Mt.Killiecrankie, and the eroded lumps of limestone on the beach at Palana from the truncated dunes. Sutherland and Kershaw (l.c.) present faunal evidence that the series is Pleistocene or in part older. At Marshall Bay, truncation by the 25 feet (7.5 m.) above MLWS bench, correlated with the Riss/Würm Interglacial sea, suggests that the limestone is older than, or at least as old as this Interglacial. In Victoria, dunes of this Interglacial age have a "travertine" crust while older dunes are lithified throughout (Gill in Jennings and Mabbutt, 1967). Some Palana Limestone Dunes have developed a crust only, e.g. at Palana. However, dunes are frequently lithified throughout and probably cover a range in time from at least the early Pleistocene to the Riss/Würm Interglacial. Jennings (1959b) discusses the opinions of authors favouring the view that any halt in glacial sea-level oscillations could foster dune development.

It should be possible to relate dune series to observed sea-level stands. On Flinders Island, however, individual Pleistocene dune series are obscured by general parabolic re-orientation. The heights reached by the limestone dunes are due at least in part, to migration of dune material up the granite slopes, as in Victoria (Gill, 1943). Thus, it is not possible at present to separate dunes older than the Riss/Würm into more than one series. The Palana Limestone Dunes are apparently much more extensive than the younger Unconsolidated Parabolic Dunes of the Island. This may be due to the presence of more than one series.

Gill (1943) does not consider present conditions adequate to account for similar dunes at Warrnambool. He postulates the presence of greater quantities of calcareous material during the Pleistocene. Derived Tertiary foraminifera within the Palana Limestone suggests part of this material originally came from erosion of calcareous marine Tertiary beds.

The following sequence of events leading to the Palana Limestone is suggested:

(a) Coastal fore-dunes formed.
(b) Parabolic dune migration followed.
(c) Dunes eroded by subsequent high seas.

The subsequent history is inferred partly from studies of the Unconsolidated Dunes. Initial soil is sandy with increase of carbonate with depth (Dimmock, 1957) causing induration. Erosion exposes the limestone on which is formed red-brown soils. Caverns develop, e.g. the limestone gorge near Ranga cut by the creek flowing east from Barclays Hill, may have developed by cave collapse.

(2) Inland Siliceous Dunes.

These occupy two principal regions on the eastern plain. They rest on surfaces from 15-20 feet to over 200 feet above MLWS. The aerial photographs reveal parabolic dune formations, with some very low and hardly discernible dune remains on the ground. The paler coloured sands compared to the dark soils of the swales clearly defines the dunes. Detailed mapping will probably reveal several series, but the present approach is generalised. Four groups are recognised.

Altmoor Sand Dunes

These are developed east of Ranga at about 200 feet above MLWS level where the Altmoor Sand partly covers a sloping plain of stratified deposits of estuarine (?) origin (Blake, 1947). The dunes are low, sometimes long, and of east-west alignment. Former hills south from The Dutchman are partly buried by them (Dimmock, 1957). This suggests the material derived from the Palana Limestone Dunes to the west. It is doubtful whether this explanation applies to all the dunes. Some may be related to Pleistocene shorelines.

Liapota Sand Dunes

East-West undulations are present in the Liapota Sand (Dimmock, 1957). Dune form is not evident and the undulations may represent translocated material derived from the Palana Dunes (cf. Altmoor Series). The Liapota Sand has covered former granite hills and buried older soils including some from the Ranga Association. Field observations and study of the aerial photographs reveal dunes which seem more appropriately assigned to old shorelines.

Bootjack Sand Dunes

These dunes are developed at about the 100 feet level north of Memana. They form a narrow belt of sandy rises belonging to the Bootjack Association of Dimmock which show some trace of parabolic form. Their appearance in aerial photographs suggests the eroded stumps of ancient dunes.

Petibela Sand Dunes

These are clearly parabolic dunes developed in the Petibela Sand below the 100 feet level, in contrast to the Bootjack Sand Dunes to the south. The trailing flanks of the parabolas are greatly elongated and have assumed a hairpin shape, pointing E. N. E. The dunes occupy several distinct regions separated by soil of the Memana Association of Dimmock. This soil is apparently developed on an old bay floor with flanking shorelines of different ages. Dimmock has described features which suggest bay bars. Some of the ridges mapped may be bars and not dunes.

(3) Trousers Point Aeolianite Dunes.

This aeolianite has considerable lime content, but is a distinct variety of the Palana Limestone Dunes. The dunes are typically developed in the Loccota District as a result of a suitable balance between siliceous and calcareous sediments.

Some of the dunes rest on the plain south of Whitemark at 20-30 feet (7-9 m.)

above MLWS inland from Lughrata Sand Dunes. Where exposed in the road cutting north of Loccota they display marked aeolian bedding. An eroded cliff of aeolianite rests on granite south of Trousers Point (Grid. 420N-890E.). It outcrops between 15 feet and 25 feet above MLWS for a distance of approximately 20 feet. Aeolian bedding is a feature and snail shells were found *in situ*. The top of the cliff conforms with the 25 feet level in this vicinity, suggesting planing by a Riss/Würm Interglacial sea. There is a dune of similar facies at the head of a former bay here. Between tide levels 5 - 6 feet above MLWS there is an outcrop of aeolianite resting on the granite shore showing that the dunes extended below present sea-level. Aeolianite boulders rest on the hillside between 50 and 100 feet in this area. There is thus evidence of higher and lower sea-levels, Holocene erosion has left a cliff face now above high tide level with vegetation at its foot.

(4) Unconsolidated Parabolic Dunes.

Stabilised dunes of loose to semi-consolidated grey sand extend inland on east and west coasts. The relatively poor soil horizon supports a considerable coastal vegetation. These parabolic dunes are at least in part older than the modern coastal foredunes of Lackrana Sand which display little or no soil development. There are two series:

Lughrata Sand Dunes

Dunes composed of Lughrata Sand are best developed in the Marshall Bay - Lughrata region (Plate 4). East-west dunes extend over one mile inland. The limestone platform on which these highly calcareous dunes rest is exposed by ancient blow-outs. At Palana (Plate 3) active blowing is most extensive, so soil development is limited.

Similar dunes are developed north of Palana, in Killiecrankie Bay, in Fotheringate Bay, in many small areas associated with beaches facing west, and elsewhere not directly associated with beaches. There are many small blow-outs.

Nala Sand Dunes (Plate 2)

Dunes of Nala Sand are extensively developed on the eastern coastal plain. North of The Patriarchs they are confined to a narrow coastal strip, but extend inland in the vicinity of "Wingaroo".

These dunes are highly siliceous. The height is below 20 feet and the alignment varies from E. S. E. - W. N. W. in the south to E. N. E. - W. S. W. in the north.

Blue Rock Sand Dunes

These siliceous dunes are developed in the Blue Rocks - Whitemark area in part within the Blue Rocks Soil Association of Dimmock. They are low dunes with east-west orientation, contemporaneous with the Lughrata Sand dunes.

Discussion

The Unconsolidated Parabolic Dunes show advanced parabolic dune development, particularly on the eastern plain. They have moved several miles inland leaving trailing flanks in places linked by small cross bars. Jennings (1957b) has discussed Landsberg's (1956) work on the relationship of summation of wind regimes to dune orientation in relation to King Island dunes. Jenkin (1968) has noted her work in relation to Gippsland dunes and has illustrated dune formation and movement. These discussions are applicable to the Flinders Island parabolic dunes. Mapping from aerial photographs reveals obvious trends comparable with wind roses from N. E. Tasmania (Davies, 1965).

(a) Origin of Dune Material.

The predominance of calcareous dunes north of Palana may be related to the following factors:

(i) Dune building at a maximum during a period of low rainfall and reduced stream erosion by Pratt's River; (ii) the apparent removal of sediment by tidal movements around North Point to Beagle Spit. A large area of sand is exposed at low tide and berm construction occurs. Sand blows are extensive. Pieces of limestone from the underlying older dunes litter the shore. Conditions favouring large populations of marine animals leaving calcareous skeletal remains would no doubt be a significant factor in the growth of extensive calcareous dunes. The east coast siliceous dunes have been built from an off-shore source. The east coast has a long history of beach ridge and dune building, but river sources of sediment are absent or insignificant at present. The few outlets are localised in their contribution. Vast quantities of sediment, however, have been moved by past drainage as evinced by the extensive beds of grit that flank the mountains and form the coastal plain. With regard to the east coast, it is postulated that tidal movements through the straits to the north and south of Flinders Island behave in a similar manner to rivers. This idea is referred to later in dealing with the beach ridges.

Siliceous dune development on the west coast is largely confined to the vicinity of Pats River, the largest stream on Flinders Island. There are extensive off-shore tidal flats here. Other west coast streams make little contribution. The presence of the Liapota Sand adjacent to the coast, sandwiched between belts of calcareous dunes, is a curious feature which may lend weight to a theory of wind deflation, or may suggest an old series of siliceous dunes developed under a different set of conditions.

It is noticeable, regarding the development of the west coast calcareous dunes that their greatest area at Marshall Bay is consistent with the absence of streams. Palana Limestone Dunes around Ranga are similarly consistent. Smaller areas, notably in the south, are very restricted and the calcareous dunes south of Whitemark are noticeably lower in carbonate. Sediment from Pats River and other small streams may be responsible.

The highly calcareous dunes at Marshall Bay are classic examples of parabolic dune development. Inland the older Palana Limestone Dunes further reflect the long history and extensive development of calcareous dunes here. A contribution of reworked material from older calcareous dunes cannot be ignored, notably at Palana. The west coast with its large tidal range and reduced exposure should be an excellent source of calcareous material.

(b) Parabolic Movements.

Although dune stabilisation is now general, there is evidence of active blowing in the past. Thus Dimmock (1957) describes two "A" horizons separated by light coloured calcareous sands indicating two active periods within the Lughrata Sand Dunes. Blow-outs have initiated movements at least twice during Holocene beach ridge development.

The formation of the Lughrata Sand Dunes and Nala Sand Dunes is apparently late Glacial to Holocene, at least in part pre-dating the beach ridge series. Major periods of blowing are thus required to account for the extensive parabolic movements in these dunes.

Initiation of parabolic dune movements on Flinders Island may have been associated with the transgression of the sea during an arid Post-Glacial Thermal

Maximum (Gill, 1955). However, Galloway (1965) and Jenkin (1968) have doubted the aridity during the Post-Glacial Thermal Maximum, and there is evidence that lagoons on Flinders Island were larger in the past.

Sprigg (1959) related increased dune movement to the "Roaring Forties" belt of high impact winds. This wind belt at present is orientated across Tasmania and wind regimes along the southern Australian coast show a south-westerly influence. The southward displacement of the "Roaring Forties" wind belt during the Tasmanian summer (Langford, 1965) suggests that, during the Post-Glacial Thermal Maximum, the greatest impact of the wind belt was south of Tasmania. If Sprigg is correct, dune movement on Flinders Island from such major blowing would be more likely prior to a Post-Glacial Thermal Maximum and there is evidence of stormy climates during the Würm (Galloway, 1965).

The Flinders Island beach ridge and foredune system developed from the post glacial maximum sea level. A similar system must have existed prior to this to provide the material for the parabolic system. Parabolic dunes of the Nala Sand Dunes abut abruptly against and are truncated by the oldest of the beach ridges. This ridge most probably represents the highest Holocene shoreline. Increased dune movements would certainly have resulted from the action of this sea-level, but it is difficult to substantiate an hyphothesis which associated the whole of the parabolic system to this cause alone.

Dunes, of the Nala series furthest inland show greater consolidation suggesting greater age. The series as a whole appears to provide evidence of two periods of major blowing, with two periods of minor blowing subsequently. These later periods observed within the Lughrata Sand Dunes and the East Coast Beach Ridges may or may not be contemporaneous. At the present time minor blow-outs show some activity. In the Palana District sand blowing is considerable.

It is suggested (i) that dune or beach ridge growth has occurred, to varying extent, with the fall and subsequent rise in sea-level during the Würm Glacial and (ii) that parabolic dune movements resulted from stillstands or fluctuations during these movements, associated with such phenomena as storm conditions and the movements of the Roaring Forty Belt. This is compatible with a theory of dune formation at Portland, Victoria (Boutakuff, 1963) and Gill's statement (1964) that "such dunes were built successively as the sea advanced and retreated".

Age of the Unconsolidated Parabolic Dunes

The Nala Sand Dunes are older than the East Coast Beach Ridges. Near Lady Barron the ridges rest on the floor of an apparent former bay. Elsewhere the presence of former shorelines and the truncation of the Nala Sand Dunes by the ridges suggest that the ridges date from a Post-glacial maximum sea-level. The Nala Sand Dunes are accordingly regarded as early Holocene and possible have their origins in the late Würm. They apparently indicate periods of extensive blowing from the east.

Although widely stabilised, the Lughrata Sand Dunes have less mature soil development and less consolidation than the Nala Sand Dunes. They occur frequently in association with beaches and appear to have been modified by frontal dune development and blow-outs, particularly at Palana. Near Leeka a frontal dune apparently truncates the parabolas. In a number of places north from Cape Frankland the dunes can be clearly seen in the aerial photographs to rest above a rocky shore not in association with beach deposits.

Frontal dune and blow-out activity has without doubt occurred within the last 100 years. The Lughrata Sand Dunes have been involved in some activity at least until this time and therefore this activity is contemporaneous with the East Coast Beach Ridges. At first sight a late Holocene age seems conclusive. The

5. View from Vinegar Hill across Opossum Boat Harbour with the Potboil in the background.

6. Aerial view of Parry's Bay looking north to Blue Rocks.

7. View across the bay south of Trousers Point, showing notching at about 100 feet above MLWS.

8. Section through dune, south of Trousers Point, looking north. Quaternary shell bed at Mr. Docker's feet. Slight soil development on this foredune is seen.

soil development is certainly of this age. However, the relationship to the shore in some areas suggests that some dunes of Lughrata Sand are older than this. They probably had their origins in late Glacial and early Holocene foredune and parabolic dunes which were overwhelmed by the Holocene rise in sea-level. This was followed by severe blowing with parabolic re-orientation. The prevailing westerly wind is ample to effect this activity. Although active movement inland may have long ceased increase in height due to additional sand being trapped by the vegetation has continued. Soil profile development therefore has remained at an early stage until very recently. However, increased development has occurred on the inland margin. W. Tuddenham (pers. comm.) has obtained a radiocarbon date of little more than 1000 years B.P. for an incipient Lughrata type soil from Wilson's Promontory.

(5) Beach Ridge and Frontal Dunes (Lackrana Sand Dunes).

Siliceous ridges and frontal dunes are present on both the east and west coasts of Flinders Island. These ridges typically parallel to the coast, are very extensive along the east coast. On the west coast they are best seen in the vicinity of Whitemark, Parry's Bay and Blue Rocks. Many other sites display varying degrees of frontal dune development, e.g. south of Trousers Point. In some instances this activity is more or less confined to reworking of slightly older calcareous dunes (Plate 8).

West Coast Dunes

At Whitemark a ridge or foredune, approximately 15 feet above MLWS, is covered with low vegetation on the upper and landward surfaces. The fauna includes numerous land mollusca. Inland another dune, approximately 30 feet in height, is stabilised by tea-tree vegetation. It shows signs of parabolic re-orientation. Further inland again, at right angles to the coast are older siliceous Unconsolidated Parabolic Dunes, regarded as approximately equivalent to the Lughrata Sand Dunes. This description applies fairly well to much of the coast from Blue Rocks to Whitemark. In the Loccota area parabolic Lughrata Sand Dunes replace the siliceous dunes. Here the frontal dune is markedly but not extensively re-oriented and modern dune growth is very slight.

Pats River is the main source of siliceous sediment for the Lackrana Dunes in the Whitemark area. The main movement is south from the river mouth. The development of a foreland has resulted in a small asymmetrical bay just north of Whitemark, analogous in miniature to the bay north of the Clarence River in N.S.W. (Jennings, 1955). Sediment moving north with the tide into Parry's Bay contributes to the extension of tidal flats and to foredunes within the bay. The source for the ridge development in the Blue Rocks area is apparently the several small streams draining into Sawyers Bay. The significant movement south tends to prolong Blue Rocks Point.

Progradation of the beach appears limited to areas under the influence of these sources of sediment. The foredune increased in height and extent *in situ*. Modern coastal dune growth indicated by freshness of form with yellow sand lacking a soil profile is relatively rare. To the south of Trousers Point the foredune rises steeply from the beach and has little vegetation cover (Plate 8). Cutting reveals slight soil development.

At Whitemark the face of the dune tends to be cliffed. Timber and bottle debris buried within is re-exposed. Little evidence of erosion was seen on the east coast of Flinders Island, but photographs by Mr. Denis Bishop show an area north of Patriarch Inlet where the sea has apparently overwhelmed and denuded ridges (Plate 9).

East Coast Beach Ridges

This siliceous ridge series is parallel to the coast for virtually its entire length. Its width varies from 0.5 to 1.5 miles. A beach berm was noted at the time of the 1957 visit. Vegetation has stabilised the ridges and is encroaching onto the beach. The close resemblance to beach ridge series elsewhere in Tasmania (Davies, 1959, 1961; Gill and Banks, 1956) is clearly revealed by comparisons of aerial photographs of Black River (Gill and Banks, 1956, plate 3), Port Sorell (Davies, 1961) and Flinders Island (Dimmock, 1957, plate 9). There are also similar series in South Australia (Sprigg, 1952), less extensively on King Island (Jennings, 1959b) and Gippsland (Jenkin, 1968).

Origin and Development

Generalisations on the origin and development of the Tasmanian and Victorian beach ridge series (Davies, 1957, 1958, 1959, 1961; Jenkin, 1968) hold true for the Flinders Island east coast. However the aspect of source of material, obviously of considerable significance, is not so clear. Gill and Banks (1956) note that at Black River, N. W. Tasmania, ridges are only prominent where there is a plentiful supply of sand. The Flinders Island East Coast Beach Ridges, while resembling other Tasmanian series in many respects also appear to exhibit significant differences. There are no bays or significant rivers to facilitate ridge growth. Such drainage as reaches the coast can have only local significance. Contemporary erosion sufficient only to explain the Whitemark ridges. The growth of the cuspate foreland at Sellar Point has been rapid. There is little if any erosion of its southern flank, as noted by Jennings (1959b) for its counterpart at Cowper Point on King Island. There is no apparent deposition on the southern flank of Sellar Point as can be seen from the map.

(a) Source of the Sediment

The east coast of Flinders Island is exposed to the Pacific Ocean, but wave action other than that of storms is affected by the gentle off shore slope (Jennings, 1955, 1959a). Progradation has proceeded over most of the coast over 40 miles long. East flowing currents in the minor straits of the Furneaux Group such as Franklin Sound, are the fastest and last the longest. In consequence "there is a substantial net transport of sediments westwards" (Jennings, 1959a). This sediment is deposited in sandy shoals (e.g. Vansittart Shoals, Pot Boil) as the Pacific swell is encountered. Jennings (l.c.) refers to "a large tidal delta some 7 miles by 5 miles across, at the southern end of the island". Beagle Spit is a similar shoal at the northern end. The turbulence and 'boiling' of the water at Pot Boil is easily seen from the summit of Vinegar Hill (Plate 5).

It is thought that the straits bear a similar relationship to the coast as would rivers as a source of sediment. It is significant that the predominant long term direction of drift of beach materials along the Tasmanian coast has carried and concentrated material on the north-east coast of Tasmania in the vicinity of the Furneaux Group Islands (Davies, 1965). Thus, a large supply of sediment is available to be carried through the straits to the east coast of Flinders Island. Further, the eastern coastal plain of the Island itself has provided material as with each Pleistocene rise of sea level a large bulk of dune material has been eroded away from much of its low lying surface. This material has been held on the continental shelf adjacent to the coast by refracted wave action. This cycle of submergence, emergence, retrogression and progradation originates from the Pliocene on evidence given later. The principle sediment source is thus off shore and probably to a large extent recycled material. A contribution is received from material deposited in the shoal areas, and which, once on the beach, is moved by beach drifting.

The removal of sediment from Bass Strait by eastward movement has been responsible for the greater development of beach ridges on the east coast off Flinders Island and for the contrast in the materials of east and west coast dunes. Thus siliceous dune development is favoured on the east coast by sediment abundance while calcareous dune development is favoured on the west by sediment paucity excepting near river mouths. The amount of material carried from Bass Strait will depend on the nature, strength, and extent of current flow in the strait. Drift bottle (Vaux and Olsen, 1961) and drift pumice (Sutherland, 1965) studies indicate that Bass Strait experiences an eastward current flow during the winter and a westward flow during the summer. The eastward winter flow is expected to be the stronger and appears to operate slightly longer than the westward flow. Past movements of materials may have been much greater than at present, particularly during Pleistocene glacial periods when the eastward winter flow would be expected greatly to dominate. Control by current activity in southern Australian waters may be one of the factors in the distribution of dune material on the southern Australian coast. Thus, calcareous dunes are characteristic from Western Australia to Victoria (e.g. Bastian, 1964; Hills, 1940; Sprigg, 1952), while siliceous dunes dominate the east coast (e.g. Thom, 1965). Tasmanian dune sands are more calcareous along the west and north coasts than on the south and east coasts, (Davies, 1965), while on King Island calcareous dunes prevail on the west coast and siliceous dunes on the east (Jennings, 1959b). This distribution possibly can be explained in part by overall prolonged eastward removal of sediment by currents corresponding to winter flow in Bass Strait. The siliceous dunes on the east coast of large Bass Strait Islands are in keeping with sediment accumulation on the side protected from dominant eastward current flow.

(b) Wave Action and Deposition

Except at Sellar Point, fetch is at a maximum in relation to the Flinders Island east coast. Babel Island is the factor in the development of the cuspate foreland. The off-shore contours indicate a gentle slope to the east across the shelf (Jennings, 1959a) and the 10 fathom contour is some 3 miles off-shore. The 5 fathom contour curves inshore from the shoals at Franklin Sound at Cameron Inlet. It is off-shore at Babel Island but close inshore near Patriarch Inlet. The greatest ridge development coincides with the greatest distance off-shore of this line, although the area just south of the Arthur River Estuary is an exception.

(c) Beach Alignment

Wave fronts on Davies' (1960) diagram of wave refraction from the south-west are co-incident with beach alignment on the west coast of Flinders Island, making due allowance for off-shore features. Beach alignment on the east coast indicates a refracted south-easterly swell. A wave refraction diagram of the south-easterly swell that fits the Ninety Mile Beach in Victoria (Bird, 1961), when extended, also fits the eastern coast of Flinders Island. This is confirmed by a study of the waves exhibited on aerial photographs.

Beach construction on Flinders Island as elsewhere is due therefore to the refracted swell from the south-east Pacific and from the south-west through Bass Strait. This sediment is a source of material for ridge building. The present east coast is largely a repetition of former alignments with modifications such as the closing of Cameron Inlet. The point of repetition of alignment from Pleistocene Interglacial is made by Davies (1960). During the last Pleistocene Interglacial a large shallow bay existed on Flinders Island, north of The Patriarchs. Ancient dunes up to 100 feet above sea level suggest that it also existed during earlier interglacials. Low sand ridges which are not certainly old dunes are most probably bay sand bars and some have associated shell beds. The soil profile described by Dimmock (1958) for such a ridge favours this explanation. The alignments appear consistent with assymetrical bays showing cuspate foreland development toward The Patriarchs, which were undoubtedly islands in the interglacial seas.

Another outcrop influenced the development of a small headland just south east of Patriarch Inlet. These granite outcrops, including Babel Island, have influenced the whole developmental history of the east coast dunes.

(6) Correlations and Comparisons between Flinders and King Island Dunes.

The New Dunes of Jennings (1959b) are Holocene in age and equivalent to the coastal Lackrana Sand Dunes on Flinders Island. His Old Dunes cannot be correlated so readily with specific Flinders Island series. At least some of the King Island Old Dunes may be correlated with Unconsolidated Parabolic Dunes on Flinders Island. Some dunes of the Nala Sand Dune Series show a stage of semi-consolidation that, although insufficient to justify an assumption of an age as great as the Riss/Würm Interglacial, may indicate a Würm Interstadial age. Some calcareous Old Dunes and aeolinites described by Jennings on King Island may probably be equivalent to similar dunes on Flinders Island regarded as Pleistocene in age. Dune movements appear to have been more extensive on Flinders Island than on King Island, due apparently to topographic differences.

3. LAGOONS AND THE COASTAL BARRIER

The lagoons comprise several types which are related to topography. West Coast lagoons are small. At Marshall Bay, elongated and bifurcated lagoons are impounded by the parabolic dunes. At Whitemark, the lagoon fauna includes fresh-water molluscs and numerous non-living shells of the euryhaline *Coxiella* are buried in the mud. There are many other small lagoons resulting from impounded drainage.

On the Eastern Coastal Plain lagoons are much more extensive, forming both inland types and coastal types related to the coastal barrier, as follows:

Old Inland Lagoons

Old sites now modified or dry occur at the base of the granite ranges and inland on the plain north of Memana. Soils of two apparently old lagoons at the foot of the Darling Range west of Nelson Lagoon differ from those of other lagoons (Dimmock, 1957).

A second series comprises Nelson (8 miles long), Wingaroo and Carnacks Lagoons, and several smaller lagoons (Wingaroo Association of Dimmock). In the Nelson Lagoon area traces of older (?) lagoons and dunes are visible. The extensive growth of this series of lagoons suggests past increased rainfall, Extensive lunettes up to 25 - 30 feet high are present on the eastern shores of these and numerous other lagoons.

Inland Lagoons of the Dune Systems

These are formed (i) by dune impounded drainage;
(ii) in the axes of parabolic dunes;
(iii) as lagoons or marshes between swales of elongated dune ridges.

Some triangular lagoons, due to dune advance into stream valleys (Jennings, 1957a) are present. Near Mt. Boyes some streams are damed on reaching the plain, but may flow further with winter rainfall. Further south several streams drain into swamps from which engrafted streams drain toward the coast. Many lagoons are much reduced in size.

Coastal Lagoons

These are impounded by the coastal barrier and beach ridge system. Cameron Inlet and the estuarine Arthur River have defined openings to the sea. Sedimentation in Cameron Inlet is more extensive and current flow meanders towards the mouth. Logan Lagoon entrance is almost completely restricted and the water is brackish.

A former connection between Burnett Lagoon and Cameron Inlet is traceable. North and South Chain Lagoons are completely enclosed, but may have been divided from others in the series by segmentation (e.g. Bird, in Jennings and Mabbutt, 1967). North from Patriarch Inlet large lagoons appear to have grown as result of impounded drainage. Some of these have lunettes. At Hogans Lagoon the lunette has encroached on the oldest beach ridge establishing an age relationship.

Coastal Barrier

The Flinders Island east coast at various times has consisted of two embayments. One, aligned to the south-east swell, curved northerly to Sellar Point. The other curved inland from the Sellar Point, Patriarchs area then north toward the Arthur River. With the rise of the Post-glacial sea-level barrier bars formed 1.5 miles or more off-shore in the south (Logan Lagoon is 1.5 miles wide, Burnett Lagoon 1 mile and Cameron Inlet is wider still). Barrier growth almost completely enclosed the whole of the coast north to Sellar Point. It may have curved to the south-west towards Cape Barren Island as a former extension of Logan Lagoon is traceable in this direction.

Similarly, the Arthur River Estuary was formed and formerly extended for six miles to the south. It is now reduced to four miles. South from the Arthur River the barrier follows the old coast truncating the parabolic dunes.

Traces of an old barrier are present particularly in Cameron Inlet where a recurved Spit marks the site. " Coffee" rock, here, is typical of dunes or beach ridges formed in the Late Pleistocene (Bird, in Jennings and Mabbutt, 1967). A marshy remnant of an older section of the Inlet or lagoon may be traced at the entrance to the East River.

Upper Quaternary shell beds thought to represent the 7.5 m. sea floor exist beneath Nelson Lagoon and may be traced in a curve towards The Patriarchs, and appear again around Wingaroo. (Sutherland and Kershaw, l.c.) Lower Pleistocene shell beds occur on the plain north from Memana (l.c.). The relationship of the shell beds with dune and lagoon systems suggests successive embayments gradually reduced to the present alignment.

Alluvial Fans

These also reflect the effect of the topography on drainage. The best example is the fan on Leventhorpe Creek near Memana. Fans are present on the western plain particularly near Blue Rocks. However, their development is rarer on the western than the eastern and northern slopes due to the short steep gradient to the coast here.

4. THE COASTLINE

Granite Platforms

Granite shores on the Island consist of rounded boulders, or sloping benches deeply incised along joint lines. Water layer levelling and flat platforms were not observed. At present sea-level traces of a notch or incipient bench appear to occur where steep granite faces are present. Older shore-lines are marked by more extensive areas of bevelled granite platform. The 25 feet (7.5 m.) shore-line at Trousers Point is markedly bevelled. Apparently there has been insufficient time for this to have taken place on the present shore.

Quaternary Shore-lines

Flinders Island supports considerable evidence of old emerged shore-lines showing similar features to those of Quaternary shore-lines described on Southern Australian coasts (Twidale, 1968). Correlative levels for Flinders Island with those measured elsewhere in Tasmania and Victoria are given in Table 1.

(a) Previous Flinders Island Literature.

Apart from Strzelecki (1845), Johnston (1879) referred to 'raised beaches' with littoral species at 40 - 50 feet (12 - 15 m.) on Furneaux Group Islands and to an oyster bed at 30 feet (9 m.) above high water level 2 miles from the mouth of the Arthur River.

Everard (1950) described beds of recent shells (Marshall Bay Coquina, Sutherland and Kershaw, l.c.) from Marshall Bay in the Lughrata District at 50 feet (15 m.) above sea-level. Granite platforms east of Heathy Valley and beach ridges representing former shore-lines paralleling the east coast are also mentioned.

Dimmock (1957) referred to marine benches cut in limestone at Lughrata at 20 - 30 feet (6. - 9 m.); a bench of siliceous deposits at about 50 - 60 feet (15 - 18.5 m.) near Ranga; a bench at about 30 feet (9 m.) at Blue Rocks.

(b) Measurement of Shore-line Heights and Correlative Literature.

The datum used in the present investigation was mean low water spring tides - MLWS - (Fairbridge and Gill, 1947). This was determined from direct measurement of intertidal ecological features. Arbitrary starting points were selected for each measurement. Hence allowance for observational error is necessary. High water level was not used because of the variation in tidal range around the Island. It is possible to establish the position of MLWS from the equivalent intertidal ecological zone, but observed HWM varies with factors affecting tidal range and with local environment. The MLWS Measurements quoted can be converted to approximate equivalent MHWS figures by addition of 10 feet (3 m.) for west coast, 5 feet (1.5 m.) for south coast and 3 feet (1 m.) for east coast localities. A summary of the main levels converted to approximate MHWS readings is given in Table 1.

On Flinders Island the investigations of the present authors indicated old shore-lines at about 200 - 250 (61 - 77 m.), 100 - 120 (30 - 37 m.), 60 - 70 (18 - 21 m.), 25 (7.5 m.) and 10 - 15 (3 - 4.5 m.) feet above MLWS. Jennings (1959b) considered that on King Island levels about 70 feet (HWM) probably can all be assigned to the Riss/Würm.

(c) 200 - 250 feet MLWS (61 - 77 m.) Shore-line.

The topography of the Flinders Island highlands suggests ancient bays with cliffed headlands above high level beach remnants. South from Loccota the granite appears to have been planed at about 200 feet suggesting a former shore-line at about this level. Limestone dune at heights of 400 - 600 feet (123 - 184 m.) are found at Palana, Lughrata and Ranga. The age of the contained fauna, their degree of lithification etc. of these dunes, suggests that their age may be such as to relate to earlier high Pleistocene sea-levels. However, precise correlations are uncertain since the levels of the toes of the dunes are largely obscured by later dunes. Limestone dunes also occur at or below present sea-level suggesting the possibility that several dune series may be represented. The 200 - 250 feet (61 - 77 m.) level may even represent the Miocene high sea-level of Bass Strait (Richards and Hopkins, 1969).

(d) 100 - 120 feet MLWS (30 - 37 m.) Shore-line.

South of Loccota benches are cut in granite at heights from below about 100 feet to some distance above (Plate 7), and there is spur flattening similar to that

FLINDERS ISLAND			KING ISLAND	N. W. TASMANIA	ULVERSTONE	TAMAR		TAS. GENERAL	S. TASMANIA	VICTORIA
Kershaw & Sutherland, this paper.			Jennings, 1959b,1961	Edwards, 1941	Chick, in Gill,1970	R. C. Kershaw, obs.		Davies in Gill,1960	Davies, 1959	Jenkin, 1968
W. Coast (HWM)	E. Coast	LWM	HWM	HWM?	HWM	HWM	LWM	HWM	HWM	LWM
0-5	7-12 (approx)	10-15	10?		3-4	0-5	10-15	2-6	2-3	7-10
15	22	20-30	20-30	5-15		15	25	12-22	12-15	20-25
					35					
				40-50	45	40	50	50		40-50
50-60	57-67	60-70	65		65	60-70	70-80	70		
90-110	97-117	100-120	120-150	100	110	90-100	100-110	120		90-100
								170		
		200-250	225					250		

TABLE 1. APPROX. CORRELATIVE TABLE, FLINDERS ISLAND AND QUOTED LITERATURE LEVELS (in feet).

observed on King Island (Jennings, 1959b).

Inland from the Arthur River Estuary ill-defined ridges are associated with a bench at 100 - 120 feet (30 - 37 m.). East from Ranga and Barclays Hill superficial E. W. dunes and ridges are superimposed on a plain of unconsolidated marine (or estuarine) sediments (Blake, 1947; Dimmock, 1957) some six miles from the coast at 100 - 120 feet elevation. Some of these ridges are younger than the Palana Limestone Dunes at Ranga and may be redeposited material derived from them. Other ridges, however, seem unlikely to have had this origin and may have been associated with old shores at these heights. However, Unconsolidated Parabolic Dunes also reach well inland here. It has not been possible in the present survey to clearly define the extent of the various series. Detailed work is required to distinguish between dunes of various ages in this area. A similar problem also occurs on the plain north of Memana where old dunes and ridges extend from 20 - 30 feet (6 - 9 m.) above MLWS to above 100 feet (30 m.). However, the lower areas of ridges are separated by low lying flats supporting soils of the Memana Association while on the higher ground inland from The Patriarchs the ridges are associated with soil of the Patriarch Series, Type D. A detailed survey should reveal evidence leading to differentiation of several dune series in the area, of which the higher ones may relate to the 100 - 120 feet shore-line.

(e) <u>60 - 70 feet MLWS (18 - 21 m.) Shore-line</u>.

Traces of this level inland from the Arthur River area are associated with sand ridges, and are much better defined than the higher level just discussed. East-west ridges of Liapota Sand inland from this level may well be, in part, former associated dunes. The western coastal plain inland from Whitemark is at 60 - 70 feet (18 - 21 m.) for about one mile before rising sharply to the basaltic plateau-like surface. This scarp is composed of granite and Mathinna Beds and probably represents a former cliff line.

South of Loccota there are granite benches at 60 feet. At Lady Barron the highest granite benches are at 60 - 70 feet. Further granite pavements near the main road at Lughrata (Everard, 1950) may also relate to this level, but their height has not been measured. The Marshall Bay Coquina here probably represents an old beach deposit. Everard (1950) quotes a height of 50 feet (15 m.) above sea-level for this deposit, but his datum base is unknown. The deposit may be related to the 60 - 70 feet (18 - 21 m.) above MLWS shore-line. Until accurate measurements are carried out there is as yet insufficient evidence to warrant reference to a 50 feet (15 m.) above MLWS shore-line on Flinders Island.

(f) <u>25 feet MLWS (7.5 m.) Shore-line</u>.

The coastal plain at Whitemark is at 20 - 30 feet (6 - 9 m.) above MLWS-the 15 feet level quoted by Dimmock apparently being measured from high tide mark. Similarly a "30" feet bench in granite and quartzite (loc.cit.) at Blue Rocks may be higher in relation to MLWS and not be a feature of the 25 feet (7.5 m.) shore-line. Jennings (1959b) has referred to difficulties in interpretation of benches at intermediate heights up to 60 feet (18 m.) on King Island. Similar difficulties appear to be present in varying degree on Flinders Island, e.g. near Loccota apparent benches are present at numerous heights up to 200 feet (61 m.). Some of this may be due to a wide tidal range at the old shores.

Clear evidence of the 25 feet (7.5 m.) shore is present at Marshall Bay where a 25 feet bench is cut in Palana Limestone and is overlain by Unconsolidated Parabolic Dunes. Further north near Leeka there are benches at 25 feet and 30 feet, the higher level being cut in limestone.

The granite shore has a marked level at 25 feet in many places, such as at Cape Frankland and Bligh Point. It may be clearly seen in the vicinity of Trousers Point. The present large bay here formerly extended inland at the southern end of Trousers Point between granite outcrops showing cliff erosion. There is eroded aeolianite which is part of the old cliff on the north side of this bay. This aeolianite is apparently bevelled by the 25 feet sea, and is in line with the bevelled granite nearby. The shell bed exposed in the bank of a lagoon 10 - 15 feet (3 - 4.5 m.) above MLWS and dominated by *Fulvia tenuicostata* may represent a deposit of this sea on the bay floor. This species, normally found on bay floors, is not an intertidal mollusc (Kershaw, 1958,Plate 11). At the head of the former bay is a dune of aeolianite of similar facies and age (?) to the bevelled aeolianite on the north side of the bay.

At Petrifaction Bay 50 yards from the beach the back shore rises sharply from 10 feet (3 m.) to 20 - 30 feet (6 - 9 m.). This level continues for some distance inland. At Lady Barron there are granite platforms at 25 - 30 feet (7.5 - 9 m.) and a littoral shell *Austrocochlea* was found buried beside one of these. To the east a 30 feet (9 m.) high cliff with consolidated grit (Opossum Boat Harbour Grit, Sutherland and Kershaw, (1971) is eroded deeply at 25 - 30 feet (7.5 - 9m.) in a similar manner to its present foot at 8 feet above MLWS. The cliff continues easterly inland before curving to the south to encompass a former bay, which may be a feature of a later 10 feet (3 m.) sea-level rather than of the 25 feet (7.5 m.) sea-level (Plates 5 and 12).

An important proportion of the eastern coastal plain is between 15 (4.5 m.) and 30 (9 m.) feet above MLWS. Old lagoons (Dimmock, 1957) between Lookout Hill and The Dutchman occur approximately at the back shore area of a 25 feet shoreline. In the Nelson Lagoon Drain (grid 550N - 050E) the Quaternary East River Coquina is exposed at a little over 10 feet (3 m.) above MLWS and possibly represents the sea floor of the 25 feet sea on the following evidence.

(1) Unconsolidated Parabolic Dunes can be traced across some of the Nelson Lagoon floor overlying the East River Coquina and clearly are younger in age.

(2) These dunes are drowned and eroded as the lagoon increased in size and are thus older at least in part to the lagoon.

(3) The parabolic dunes have been truncated by a possible 10 feet (3 m.) Holocene sea so that the underlying East River Coquina must be older than this and probably Pleistocene in age.

(4) The freshness of many of the shells in the Coquina suggest a late Pleistocene age. Its position and height indicate correlation with the 25 feet (7.5 m) shore-line.

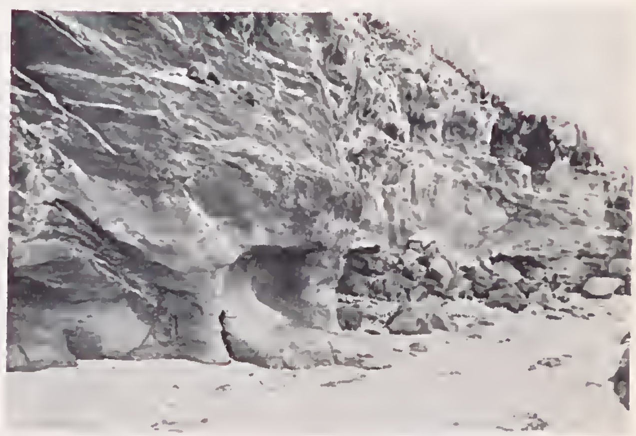
(5) The Coquina has been located at a series of points in the area suggesting the proximity of a shore-line, (Sutherland and Kershaw, 1971).

North from Memana the eastern coastal plain has been the site of embayments of shallow muddy facies. The 25 feet (7.5 m.) sea-level is the last likely occupant of the wide area between 15 - 25 feet (4.5 - 7.5 m.) above MLWS. Low ridges with water worn quartz grit apparently former bay bars overly a sub-surface calcareous horizon that passes down into shelly sands (including the Cameron Inlet and Memana Formations). The upper horizons of these shell beds contain shells of *Ostrea angasi* (*sinuata*, Dimmock, 1957). The East River Coquina has been identified at several sites near 'Wingaroo'. Further inland on the plain there are dunes and ridges probably indicating the sites of various shore-lines. Beneath the ridges stratified materials of sandy clay loam, clayey grit, and clay overly the carbonate layer in places. This suggests: (1) the superficial (beach deposit or bar) nature of the ridges, (2) that the underlying shell beds here probably belong to the horizons older than the 25 feet which has reached its limit.

9. East Coast looking north from Patriarch Inlet showing erosion of Beach Ridges.

10. Section through Palana Limestone Dune near "Fairhaven" turn off, Lughrata, in road cutting.

11. Lagoon south of Trousers Point, looking north-east. Quaternary *Fulvia* bed at water level on right.



12. Cliff of Opossum Boat Harbour Grit showing erosion. (Photographs by D. J. Bishop and R. C. Kershaw.)

On the western Arthur River Estuary shore Quaternary coquinas are exposed in the cliff face at 13 - 16 feet (4 - 5 m.) and 10 - 11 feet (3 m.) above MLWS. Sutherland and Kershaw, l.c.). A plausible sequence of events in the area is:

(1) Deposition of the grey sand (Liapota Sand during a higher sea-level. Possible evidence of a 60 feet (18 m.) shore-line in the area has already been noted. A stream channel was cut following withdrawal.

(2) The stream channel is infilled during a marine transgression of about 20 - 30 feet (6 - 9 m.) above MLWS, depositing the coquina. The steep sides of the channel may have been due to rapid stream erosion, or due to erosion when the sea rose within its confines.

(3) Barrier growth follows with lagoonal conditions initiated. Evidence of such a lagoon remains.

(4) The 20 - 30 feet (6-9 m.) sea withdraws with the onset of the Würm Glacial. Drainage possibly follows the present estuary course.

(5) With the rising post-glacial sea as discussed earlier, barrier ridges are breached. Gill (1970) has drawn attention to a possible interstadial sea-level similar to the present so that the matter may be much more complex. Major re-orientation of dune material follows. These Nala Sand dunes are blown well inland. Their alignment can apparently be traced from the present barrier across the Arthur River Estuary to the plain on the western shore.

(6) Continued rise of sea-level (the 10 - 15 feet (3 - 4.5 m. sea?) cuts through the barrier flooding lagoons and stream drainage inland towards Wingaroo, forming the Arthur River Estuary. Nala Sand Dunes are truncated by the shore-line.

(7) An apparent small withdrawal of sea-level follows, leaving evidence of its former presence on the barrier in the form of a small dry bay with beach and offshore bars, and a growing series of beach ridges associated with barrier growth. To the south toward Wingaroo from the present estuary apparent old shore-lines and ridges that extend from both arms of the estuary indicate its recent limits. These marshy areas and ridges belong to the Lackrana Sand which includes the barrier ridges.

Further evidence of a late Pleistocene barrier may be indicated by the presence east from Wingaroo of traces of old ridges at right angles to the parabolic dunes. In Cameron Inlet G. M. Dimmock (pers. comm.) observed "coffee rock", a type of profile often developed in older ridges. Jenkin (1968) in Victoria and Thom (1965) in New South Wales, have discussed evidence for the presence of late Pleistocene barriers in the areas studied by them.

(g) The 10 feet MLWS (3 m.) Shore-line.

The coastal physiography indicates many traces of recent shore-lines slightly above the present one. Old beaches and cliffs, now largely unaffected by the sea, are most frequent in sheltered positions such as in Logan Lagoon and the various Inlets. As with King Island (Jennings, 1959b) the most likely interpretation is of a recent uniform emergence on Flinders Island of about 10 - 15 feet. Inlets such as the Arthur River, are now obviously reduced in size. Opossum Boat Harbour was apparently much larger prior to the present. The backshore behind its eastern shore extends inland for some distance at between 10 (3 m.) and 15 feet (4.5 m.) above MLWS, to the cliffline enclosing the old bay. Lackrana sand ridges rest on this surface (Plate 5).

On the west coast, Parry's Bay. where a 10 - 15 feet shore-line is traceable around much of the bay, is an example of a formerly larger bay (Plate 6,9). A platform surface cut in basalt, limestone and silicified grit, with siliceous sand and unconsolidated gravel resting on the surface, is at approximately 12 feet above MLWS. The foredune continues to the north away from the present bay shore-line and is related to the older shore-line. It is firmly stabilised with vegetation (Plate 6). At Petrifaction Bay the backshore is levelled at 10 feet above MLWS and its surface is the Petrifaction Bay Coquina, a near shore and littoral deposit containing a fauna identical to the present fauna of the Bay. A similar shell bed occurs behind the granite shore at Palana at 10 - 15 feet (3 - 4.5 m.) above MLWS. The coquina in the fore-dune in the bay south of Trousers Point at 15 feet above MLWS possibly may represent the high tide level of this former sea. A Holocene age is considered likely for most of the 10 - 15 feet (3 - 4.5 m.) features, but some may be features of a similar late Pleistocene level, e.g. the coquina in the western shore of the Arthur River Estuary at 11 feet above MLWS. On the Opossum Boat Harbour beach, R. W. T. Wilkins (pers. comm.) found *Anadara trapezia* and *Pyrazus ebininus* apparently washed up on the shore. These species do not live on the coast now and their presence indicated derivation from a deposit of a warmer sea of late Pleistocene or Interstadial or Post-glacial age.

Parabolic dunes along most of the eastern coast are truncated by a barrier with beach ridges now paralleling the shore and constituting the Lackrana Sand Dunes. Hails (1965) reaffirms the view that barriers are features of submerged coasts; a view compatible with the complex history of the Flinders Island coast. The development of the present barrier probably commenced initially on submergence of the coast by the Post-Würm Glacial sea. At its highest level this sea apparently cut the barrier. Old shore-lines are visible around the whole circumference of the former arms of the Arthur River Estuary. The rise to a 10 feet level may thus possibly have been rapid. Washover channels on the barrier at the Arthur River are apparently a more recent feature, however, and with shore-lines observed within east coast inlets may indicate fluctuations of sea-level. Teichert (1950) has described evidence of post - 10 feet (3 m.) features on Rottnest Island. The barrier ridges on Flinders Island are not uniform but display two or more periods of active blowing.

The opinions of Authors on a Post-glacial high sea are divided on the validity of evidence or its presence in the areas studied by them. There is no doubt that much of the evidence presented above is Post-glacial, and lends strong if not conclusive support for the theory. A buried coquina near HWM at Yellow Beach, Lady Barron, indicates that retreat from any such high sea would have occurred more than 4,000 years ago (Sutherland and Kershaw, l.c.).

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